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Effects of Chronic Exercise on Feelings of Energy and Fatigue: A Quantitative Synthesis

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The authors investigated the effect of chronic exercise on feelings of energy and fatigue using meta-analytic techniques. Chronic exercise increased feelings of energy and lessened feelings of fatigue compared with control conditions by a mean effect delta of 0.37. The effect varied according to the presence or absence of a placebo control or whether chronic exercise was completed alone or in combination with an additional therapy. Investigations that used a placebo control and examined chronic exercise alone found no effect of chronic exercise on feelings of energy and fatigue. Certain placebo controls may increase feelings of energy and lessen feelings of fatigue when used with older adults or people with psychological distress. The results highlight the need for research identifying the most useful control conditions for accurately interpreting mental health outcome data obtained in chronic exercise investigations.

Keywords: meta-analysis, mood, physical activity, placebo, vigor

Feelings of low energy and fatigue are a major public health problem. Although less than 1% of the population suffers from chronic fatigue syndrome, persistent fatigue is reported by about 20% of adults in community samples (Wessely, Hotopf, & Sharp, 1998). Fatigue is among the most common reasons for doctor visits, yet it is often inadequately treated by health care providers (Lange, Cook, & Natelson, 2005). Widespread dissatisfaction with fatigue is suggested by the fact that U.S. consumers spend billions of dollars annually for products aimed at improving feelings of energy (Packaged Facts, 2004). Society could benefit from a better understanding of the efficacy of interventions aimed at increasing feelings of energy and lessening feelings of fatigue.

One promising intervention for feelings of low energy and fatigue is chronic exercise. *Chronic exercise,* also known as *exercise training,* refers to cumulative, acute bouts of physical activity that are planned, structured, and repeated and result in improvement or maintenance of one or more components of physical fitness, including cardiorespiratory capacity, muscle strength, body composition, and flexibility (Caspersen, Powell, & Christenson, 1985). *Physical activity* refers to skeletal muscle activation resulting in energy expenditure beyond that of a resting level.

Population-based studies show that physical inactivity is consistently associated with fatigue (Puetz, 2006). Sedentary groups with fatigue-related medical conditions show increased feelings of energy and lessened feelings of fatigue after chronic exercise (e.g., Dimeo, Stieglitz, Novelli-Fischer, Fetscher, & Keul, 1999; Noreau, Martineau, Roy, & Belzile, 1995; Petajan et al., 1996; Singh, Clements, & Fiatarone, 1997; Stanton & Arroll, 1996; Steptoe, Edwards, Moses, & Mathews, 1989; van Santen et al., 2002). A previous literature review, however, concluded that chronic exercise performed by healthy adults had equivocal effects on feelings of energy and fatigue and suggested that weakness in research designs contributed to the inconsistent results (O'Connor & Puetz, 2005). Research design weaknesses also have limited the ability of investigators to draw causal inferences and accurately examine variables that related literature has suggested as potential moderators of the effect of chronic exercise on feelings of energy and fatigue. Relevant variables include age (Crombie et al., 2004); medical status (Stewart et al., 1994); baseline anxiety and depression symptoms (Chen, 1986); and intervention characteristics, such as the exercise mode or the exercise program duration (Dunn, Trivedi, & O'Neal, 2001). The current review presents descriptive data for these variables because many studies did not report information about these variables and there were too few studies in the literature for a powerful test of numerous moderators (Hedges & Pigott, 2004). The main focus of the review is on clarifying the role of two fundamental research design issues in moderating the effect of chronic exercise on feelings of energy and fatigue—the specificity of chronic exercise intervention and the type of control condition.

The effect of chronic exercise on feelings of energy and fatigue has been unclear in experiments that have used a nonspecific intervention. Chronic exercise interventions are specific when exercise is the sole intervention and are nonspecific when another therapy, such as drug or cognitive–behavioral therapy, is added to exercise training (e.g., Gowans, deHueck, Voss, & Richardson, 1999). The independent effect of chronic exercise on feelings of energy and fatigue is unknown when another therapy for fatigue is added. When chronic exercise has been completed in conjunction with a second therapy, only a few investigators have included an exercise-only comparison condition (e.g., Donta et al., 2003). Consequently, it is unclear whether there is an additive effect on

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feelings of energy and fatigue when a second therapy is added to a chronic exercise intervention. It is also unknown whether intervention specificity interacts with the type of control condition used.

Variations in control conditions used in chronic exercise studies have made it difficult to interpret the literature on chronic exercise and feelings of energy and fatigue. Controls used in the literature on chronic exercise and feelings of energy and fatigue have ranged from no-treatment controls to placebo control conditions that involved participants in substantial physical or cognitive activities. Placebo controls—for example, yoga and health education programs—often contain features included in chronic exercise programs that may be therapeutic, such as stretching exercises and opportunities for social interaction. Accurately interpreting the literature on chronic exercise and feelings of energy and fatigue is difficult because some control conditions used in chronic exercise investigations may be therapeutic. For example, if yoga is an efficacious therapy for fatigue, then the effect of chronic exercise has been underestimated in studies that have used yoga as a control. Because there is no consensus as to the most appropriate control conditions for interpreting data from chronic exercise experiments, there is a need to determine whether energy and fatigue outcomes are influenced by the type of control conditions selected.

Meta-analysis is a tool that can be effectively applied to the literature examining the influence of chronic exercise on feelings of energy and fatigue. Meta-analysis can quantify the extent to which key features of a research design, such as the specificity of exercise interventions and the type of control conditions, moderate changes in feelings of energy and fatigue associated with chronic exercise. A meta-analytic review of the chronic exercise and fatigue literature also is timely because there are no comprehensive reviews on this topic. The few available reviews either were narrow in scope and failed to put the findings in the full context of the relevant medical, psychological, and exercise literatures (Stevinson, Lawlor, & Fox, 2004) or were open to selection bias (O'Connor & Puetz, 2005). We can obtain a better understanding of the extant literature by taking advantage of the strengths of meta-analysis. The advantages include uniform criteria for study selection, consistency in how research is summarized, quantitative precision, and avoidance of small sample bias through combination of effects. A meta-analysis could provide pertinent information about the magnitude and variability of the effect of chronic exercise on feelings of energy and fatigue, moderators of the effect, the generalizability of the results, and directions for future research.

This investigation has two primary purposes. One is to use meta-analytic methods to quantify the magnitude and variability of the effect of chronic exercise on feelings of energy and fatigue. The other is to determine the extent to which the effect is moderated by two key research design variables—the specificity of the exercise intervention and the type of control condition. A secondary purpose is to provide descriptive information about other plausible moderators, including age, medical status, baseline anxiety and depression symptoms, and the intervention characteristics of exercise mode and exercise program duration.

Method

Literature Search

Chronic exercise studies that used an outcome measure that included questions assessing feelings of energy or fatigue were located from searches of the PsycINFO, PubMed, and Web of Science computer databases from January 1945 to November 2004, with *energy*, *exercise*, *fatigue*, *mood*, *physical activity*, *Profile of Mood States*, *POMS*, *quality of life*, *resistance training*, *SF-36*, and *vitality* as keywords. Searches were supplemented by reference lists from retrieved articles and colleagues. Criteria for inclusion were that (a) the independent variable involved a chronic exercise program of at least 3 weeks, (b) the dependent variable was a measure of energy or fatigue (see Table 1) that was assessed before and either during or immediately after an intervention involving chronic exercise, and (c) the design was experimental. Investigations aimed at understanding psychological consequences of intense exercise training in ath-

Table 1
Dependent Measures of Energy and Fatigue

Name of measure (reference)	No. of Studies
1. Medical Outcomes Study Short Form–36: Vitality (Ware, 1993; Ware & Sherbourne, 1992)	27
2. Profile of Mood States: Vigor (McNair et al., 1992)	26
3. Profile of Mood States: Fatigue (McNair et al., 1992)	22
4. Fibromyalgia Impact Questionnaire: Fatigue (Burckhardt et al., 1991)	4
5. Functional Assessment of Cancer Therapy: Fatigue scale (Yellen et al., 1997)	4
6. Chalder Fatigue Scale (Chalder et al., 1993; De Vries et al., 2003)	3
7. General Well-Being Schedule: Energy (Fazio, 1977)	3
8. Linear Analogue Self-Assessment Scale: Fatigue (H. J. Sutherland et al., 1988)	3
9. Visual Analogue Scale: Fatigue	2
10. Multidimensional Fatigue Inventory (Smets et al., 1995)	2
11. Author-developed categorical scale: energy–fatigue (Roviaro et al., 1984)	1
12. Linear Analogue Self-Assessment Scale: Energy (H. J. Sutherland et al, 1988)	1
13. Beck Depression Inventory: Fatigue subscale (Beck et al., 1961; Dozois et al., 1998)	1
14. Multiple Sclerosis Quality of Life: Energy (Vickrey et al., 1995)	1
15. Nottingham Health Profile: Energy (Essink-Bot et al., 1997; Hunt & McEwen, 1980)	1
16. Quality of Life in Epilepsy Inventory: Energy (Devinsky et al., 1995)	1

Note. The total number of studies listed here ($n = 102$) is larger than the total number of studies collected for the analysis ($n = 70$) because many studies used more than one measure as an outcome variable.

letes were excluded (O'Connor, 1997). Studies examining the effect of a single bout of exercise on energy and fatigue were excluded. The chronic effect of exercise was not confounded by transient effects of an acute bout of exercise in any of the included studies.

Study Characteristics

Seventy studies of 6,807 subjects were included. The 70 studies had a median sample size of 57 (range = 13–1,092). Sixteen of the 70 effects (23%) were derived from groups with no medical condition, and 54 of the effects (77%) came from investigations with patient groups. The medical conditions contributing the largest number of effects were cancer patients and survivors (17%); patients with chronic fatigue, fibromyalgia, or an unexplained illness characterized by fatigue symptoms (17%); cardiac rehabilitation patients (10%); and patients with anxiety and/or depression disorders (7%). The preintervention energy–fatigue score (mean and standard deviation) was within the expected range (T score of 47.0 ± 7.7, with lower scores indicative of greater fatigue). Mean age was 50 ± 14 years. Chronic exercise programs averaged 13 ± 7 weeks in duration, with 3 ± 1 sessions per week. The exercise sessions averaged 45 ± 17 min in duration at an intensity of 54% ± 13% of estimated maximal aerobic capacity.

Effect Size Calculation

We calculated effect sizes by subtracting the mean change for a control group or condition from the mean change for an experimental group or condition and dividing this difference by the pooled standard deviation of pretest scores (Hedges & Olkin, 1985). We adjusted all effect sizes using Hedges and Olkin's (1985) small sample size bias correction before entering them into the analysis. We calculated effect sizes so that increases in feelings of energy and decreases in feelings of fatigue resulted in positive effect sizes. In studies in which multiple effects could be obtained (e.g., studies with separate results for men and women), we averaged effects so that only one value contributed to the analysis (Gleser & Olkin, 1994).

When precise mean data were not reported, effect sizes were estimated (Rosenthal, 1991) from F tests (Blumenthal, Williams, Needels, & Wallace, 1982; Roviaro et al., 1984), p values (Stanton & Arroll, 1996), or figures (Mostert & Kesselring, 2002). For studies in which precise standard deviations were not reported (Burckhardt, Mannerkorpi, Hedenberg, & Bjelle, 1994; Gowans et al., 1999; MacVicar & Winningham, 1986; Mock et al., 1994, 1997), the standard deviation was drawn from published norms or the study with the largest sample.

Statistical Analyses

A macro (SPSS, Version 13.0) was used to calculate the aggregated mean effect size delta, the associated 95% confidence interval, and the sampling error variance according to a random effects model (Lipsey & Wilson, 2001, pp. 208–212). Random effects models were used to account for between-studies heterogeneity associated with both study-level sampling error and random effects variance (Lipsey & Wilson, 2001, pp. 124–125, 140–142, 216–220). In this model, each effect was weighted by the inverse of its variance and then reestimated after the random effects variance component was added (Hedges & Olkin, 1985). This procedure was used in all subsequent random effects analyses. Heterogeneity was indicated if Q_T (the sum of squares of each effect of the weighted mean effect; Hedges & Olkin, 1985, p. 123) reached a significance level of $p \leq .05$ and the sampling error accounted for less than 75% of the observed variance (Hedges & Olkin, 1985, pp. 191–200). We computed the weighted fail-safe sample size to estimate the hypothetical number of unpublished or unretrieved studies of null effect and mean weight necessary to reduce the significance of the mean effect to .05 ($N+$; Rosenberg, 2005).

Primary moderators. The three primary moderator variables were the type of control condition, the intervention specificity, and the interaction of the control condition and intervention specificity variables. The literature allowed for a meaningful statistical comparison when the control condition variable was coded into two categories: no treatment–usual care controls and placebo controls. In the available literature, about one half of the placebo control conditions involved muscle-stretching exercises, and the other half focused on more cognitively oriented activities, such as completing mental tasks or attending health education classes. The intervention specificity variable also was coded into two categories, exercise alone and exercise completed in addition to another treatment. No treatment–usual care controls were used in 37 experiments that included an exercise-alone intervention and in 22 experiments that combined exercise with an additional therapy. Placebo controls were used in 8 experiments that included exercise-alone interventions and 3 experiments that combined exercise with an additional therapy (see Figure 1).

Primary moderator analysis. We entered the primary moderator variables into a weighted least squares multiple linear regression analysis to determine their independent effects ($p \leq .05$) on variation in effect size (Hedges & Olkin, 1985, pp. 167–188). We used a macro (SPSS, Version 13.0) for the analysis that used a mixed effects model. We decomposed significant moderators in the regression analysis using a random effects model to compute effect sizes and 95% confidence intervals (Lipsey & Wilson, 2001, pp. 212–216). We determined differences among the levels of significant moderators using the Q_B statistic (i.e., the difference between Q computed within each moderator level and Q computed across moderator levels). Bonferroni post hoc contrasts were tested at $p \leq .05$.

Secondary moderators. Secondary moderator variables were selected on the basis of an adequate database and logical, theoretical, or prior empirical relation with energy and fatigue. The variables included were age, exercise program duration, exercise mode (i.e., exercise categorized as aerobic, e.g., walking or biking; strength training exercise, e.g., weight lifting; combined exercise regime that included aerobic, strength, and flexibility components), medical condition (i.e., cancer patients and survivors; cardiac rehabilitation patients; fibromyalgia patients; patients with psychiatric disorders, i.e., anxiety, behavior and depressive disorders; individuals with no medical condition; and patients in a catch-all category labeled *other medical conditions,* i.e., arterial claudication, arthritis, chronic fatigue, diabetes, epilepsy, kidney disease, growth-hormone deficiency, Gulf War syndrome, hypertension, multiple sclerosis, muscular dystrophy, obesity, and unexplained physical symptoms), preintervention anxiety score, and preintervention depression score. We standardized preintervention anxiety and depression symptom scores (i.e., transformed to T scores on the basis of available norms) to combine scores across different measures.

Secondary moderator analysis. For the secondary moderator analyses, we used macros (SPSS Inc., Chicago IL, Version 13.0) to compute effect sizes and 95% confidence intervals for continuous and categorical variables (Lipsey & Wilson, 2001, pp. 120–121, 135–138, 212–216). These moderator analyses used a mixed effects model to account for heterogeneity of moderator effects.

Results

The distribution of the 70 effects was skewed positively ($g1 = 1.10$) and leptokurtic ($g2 = 1.60$). Sixty-six of the 70 effects were greater than zero, and the percentage of effects greater than zero was equal for groups with and without a medical condition (94% for both groups). The mean effect size delta was 0.37 (95% confidence interval = 0.29, 0.45). The significant increase in feelings of energy and decrease in feelings of fatigue after chronic exercise training ($z = 8.97$, $p < .001$) was heterogeneous, $Q_T(69) = 126.22$, $p < .001$. Sampling error accounted for 61.6% of the observed variance. The fail-safe sample size was 2,216.

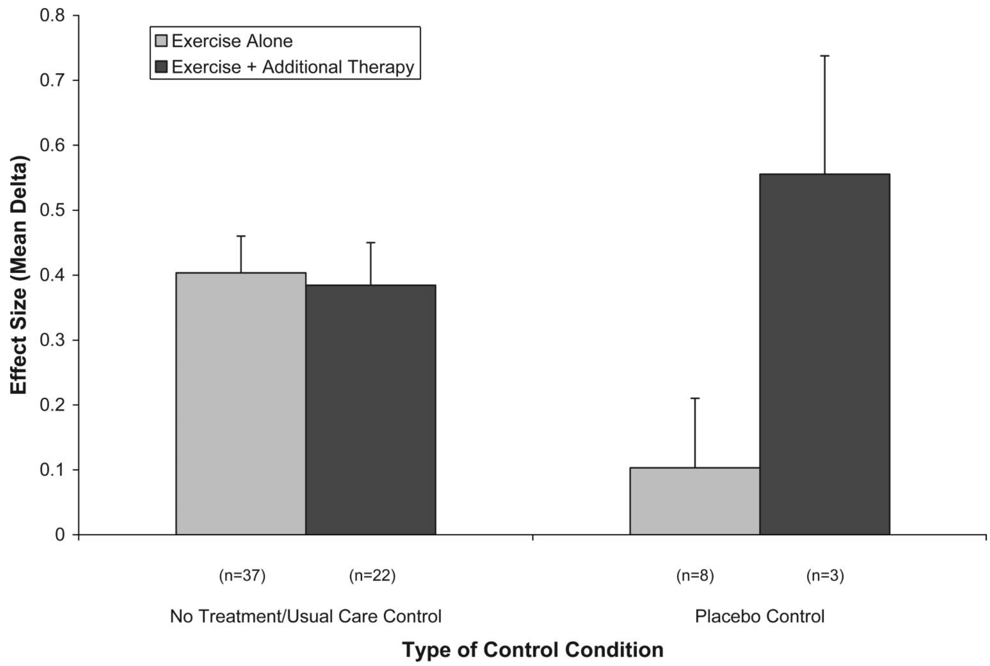

Figure 1. Mean (plus or minus standard error) effect sizes illustrating the Control Condition × Intervention Specificity interaction.

Primary Moderator Analyses

The overall multiple regression model was significantly related to effect size. Q regression model (Q_R) is a test of the regression model, $Q_R(3) = 7.61$, $p = .05$, $R^2 = .10$. Q residual (Q_E) is an estimate of the random effects variance component after accounting for the moderator variables, $Q_E(66) = 71.40$, $p = .30$. The interaction of the control condition and intervention specificity variables ($\beta = .47$, $z = 2.06$, $p = .04$) was independently related to effect size. The interaction is illustrated in Figure 1.

Decomposition of the interaction of the control condition and intervention specificity variables showed that the magnitude of the effect was significantly smaller for investigations that used a placebo control and examined chronic exercise alone (mean $\Delta =$ 0.10, 95% confidence interval = −0.11 to 0.31), when contrasted with the average effect for other Control Condition × Intervention Specificity combinations, $Q_B(1) = 7.04$, $p = .01$. Among these other combinations, effect sizes of similar magnitude were found. The effect size for chronic exercise interventions with an additional therapy that used a placebo control was 0.55 (95% confidence interval = 0.20, 0.91). The effect size for interventions that used no treatment–usual care controls with chronic exercise alone was 0.40 (95% confidence interval = 0.29, 0.51). Finally, the effect size for interventions that used no treatment–usual care controls and chronic exercise combined with an additional therapy was 0.38 (95% confidence interval = 0.26, 0.51).

Secondary Moderator Analyses

Descriptive results for continuous variables are reported as univariate standardized regression coefficients. The results were as follows: age = 0.05 (95% confidence interval = −0.19, 0.29; number of effects = 67), preintervention anxiety = −0.26 (95% confidence interval = −0.54, 0.06; number of effects = 39), preintervention depression = −0.13 (95% confidence interval = −0.43, 0.19; number of effects = 40), and exercise training duration = −0.08 (95% confidence interval = −0.31, 0.16; number of effects = 69). Univariate results for categorical moderators are presented in Table 2.

Discussion

Magnitude of the Effect

Chronic exercise was associated with improved scores on measures of feelings of energy and fatigue. The magnitude of the effect ($\Delta = 0.37$) represents a clinically important increase in feelings of energy and decrease in feelings of fatigue (Schwartz et al., 2002). The effect size is similar to standardized effects (Hedges's g) of chronic exercise on other aspects of mental health, such as cognitive function ($g = \sim 0.30$; Colcombe & Kramer, 2003) and symptoms of depression ($g = \sim 0.50$; North, McCullagh, & Tran, 1990).

The magnitude of the effect of chronic exercise on increasing feelings of energy and lessening feelings of fatigue appears to be larger than that of cognitive–behavioral or drug treatments. For example, a randomized controlled trial of 1,092 Gulf War veterans compared chronic exercise with cognitive–behavioral therapy (Donta et al., 2003). Twelve weeks of chronic exercise had a significantly larger effect on reducing general fatigue scores when compared with the effect of cognitive–behavioral therapy alone (Hedges's $g = 0.19$). In addition, although the effect of chronic exercise on feelings of energy and fatigue has not been directly compared with the effect of drugs used in the treatment of fatigue, the average effect of chronic exercise on feelings of energy and

Table 2
Univariate Categorical Moderator Analysis

Moderator variable	k	Mean Δ	95% confidence interval
Medical condition			
Psychiatric disorder	5	0.56	0.21, 0.90
Cardiac rehabilitation	7	0.48	0.22, 0.74
No medical condition	16	0.38	0.20, 0.55
Cancer patient/survivor	12	0.36	0.14, 0.57
Other medical conditions	23	0.34	0.20, 0.49
Fibromyalgia	7	0.30	0.03, 0.56
Exercise mode			
Strength training	7	0.48	0.21, 0.76
Combined modes	21	0.38	0.26, 0.50
Aerobic exercise	44	0.36	0.29, 0.43

fatigue found in the present analysis is larger than effects reported for stimulant drugs, such as amphetamine and methylphenidate, as well as less addictive substances, such as the novel wake-inducing agent modafinil (Lange et al., 2005). For example, in a sample of 72 multiple sclerosis patients, fatigue scores improved by 0.23 standard deviation (Hedges's g) when patients took modafinil (200 to 400 mg/day) daily for 1 month, compared with those patients who took a placebo (Rammohan et al., 2002). Compared with other treatments, the magnitude of the effect of chronic exercise on increasing feelings of energy and decreasing feelings of fatigue supports the recommendation made elsewhere that chronic exercise is suitable for treating fatigue in primary care settings (Lange et al., 2005). One advantage of chronic exercise therapy for fatigue is that it can be implemented more easily and inexpensively than cognitive–behavioral and drug treatments.

Primary Moderators of the Effect

The effect of chronic exercise on feelings of energy and fatigue was independently moderated by an interaction between the type of control condition and the specificity of the exercise intervention. Compared with studies with other designs, investigations that used a placebo control and examined chronic exercise alone yielded a smaller mean effect (Hassmen & Koivula, 1997; King et al., 2000; Peters, Stanley, Rose, Kaney, & Salmon, 2002; Redondo et al., 2004; Singh et al., 1997; Steptoe et al., 1989; Stiggelbout, Popkema, Rock, de Greef, & van Mechelen, 2004; Valim et al., 2003). Because the effect did not differ statistically from zero, our results suggest either that chronic exercise alone is a placebo or that placebo controls are treatments. A review of the experiments that generated this effect provides evidence that the placebo controls often appeared to be treatments.

Three primary factors appear to have contributed to the increase in feelings of energy and decrease in feelings of fatigue after placebo control conditions in experiments that involved chronic exercise alone. One factor is the nature of the placebo controls used. A second factor is the higher percentage of investigations focused on groups of older adults (mean age ≥ 60 years). A third factor is the higher percentage of investigations in which the samples were characterized by preintervention elevations in the psychological symptoms of anxiety and depression.

Placebo controls and older adults. Increased feeling of energy and lessened feelings fatigue were achieved with the use of certain placebo controls, especially in studies involving older adults. Although the descriptions of placebo controls in the experiments that involved chronic exercise alone were cursory, they suggested that placebo controls were more effective in the experiments that involved chronic exercise alone because a high percentage of these investigations used placebo controls that appeared to be an effective therapy for fatigue when used with older adults. Thirty-eight percent of the experiments with placebo controls that involved chronic exercise alone focused on samples of older adults. None of the placebo control experiments in which a second therapy was added to chronic exercise focused on older adults. The most commonly used placebo controls were stretching and health education.

Twenty-five percent of the placebo controls in experiments that involved chronic exercise alone used a health education program (Singh et al., 1997; Stiggelbout et al., 2004), and none of the investigations that added a second therapy to chronic exercise used a health education control. Although health education is not recognized as a treatment for fatigue (Lange et al., 2005), health education was associated with increased feelings of energy and lessened feelings of fatigue among older patients with chronic disease in at least one investigation. A 6-month randomized controlled trial with 942 heart disease, lung disease, stroke, and arthritis patients found that a self-management health education program significantly increased feelings of energy and lessened feelings of fatigue compared with a no-treatment control (Lorig et al., 1999). Because decreased disability and increased weekly minutes of exercise also occurred, those results suggest a possible influence of health education on increased physical activity and a concomitant reduction in feelings of fatigue among older medical patients. Health education could have greater effects (expected or actual) on physical activity and fatigue among older people compared with younger adults because sensory and motor function decline with aging (Carter, McKenna, Martin, & Andresen, 1989).

Stretching programs were the most frequently used placebo control in experiments that involved chronic exercise alone (King et al., 2000; Peters et al., 2002; Steptoe et al., 1989; Valim et al., 2003), whereas programs that included or emphasized muscular relaxation were more common among investigations that added a second therapy to chronic exercise (Fulcher & White, 1997; Partonen, Leppamaki, Hurme, & Lonnqvist, 1998). Increased strength in older adults after stretching interventions suggests that stretching can be a moderate-intensity exercise in this population (Agre, Pierce, Raab, McAdams, & Smith, 1988). Therefore, chronic stretching programs may be an effective treatment for fatigue, especially among older adults, whose lack of strength and flexibility can limit their physical function.

Regular, voluntary stretching is a form of chronic exercise because skeletal muscle actions by certain muscle groups cause other muscle groups to be stretched, and this results in increased flexibility, one component of physical fitness (Caspersen et al., 1985). One key distinction between voluntary stretching and aerobic exercise is that stretching usually is performed at a lower relative intensity. *Relative exercise intensity* refers to intensity expressed in relation to a physiological capacity or maximal ability, such as the percentage of maximal aerobic capacity or maximal strength. If increased feelings of energy and lessened feelings of fatigue can be realized from low-intensity chronic exercise, as is suggested by the epidemiological evidence (Puetz, 2006), then typical voluntary stretching programs may be a treatment for fatigue. If moderate-intensity exercise is required to consistently increase feelings of energy and lessen feelings of fatigue, as is suggested indirectly by experiments examining other health outcomes, including symptoms of depression (Dunn et al., 2001; Kesaniemi et al., 2001), then typical stretching programs are not a treatment for fatigue, but they might be an effective placebo for moderate-intensity chronic exercise. The relative intensity of stretching programs depends in part on the physical condition of the group being studied. There is a greater chance that a stretching program will represent a relatively moderate intensity of exercise for older adults because their physical capacity is typically low compared with that of younger adults.

In short, studies of chronic exercise alone that used a placebo control frequently tested older adult samples and were characterized by stretching control conditions. Thus, it is possible that the smaller effect of chronic exercise on feelings of energy and fatigue among these studies resulted in part from the fact that the stretching programs more often were of a relatively moderate intensity.

Symptoms of psychological distress. Increased feelings of energy and decreased feelings of fatigue after placebo conditions in the experiments that involved chronic exercise alone might have occurred in part because the participants tested were characterized by preintervention elevations in the psychological symptoms of anxiety and depression. People who had these characteristics might have been more prone to respond positively to the placebos used in chronic exercise investigations for the reasons we describe.

Twenty-five percent of the placebo-controlled experiments that involved chronic exercise alone focused on testing depressed older adults or participants with elevated symptoms of anxiety (Singh et al., 1997; Steptoe et al., 1989). None of the investigations that added a second therapy to chronic exercise had this focus. People with psychological distress and patients with mental health disorders, especially anxiety and depression (Chen, 1986; Lawrie, Manders, Geddes, & Pelosi, 1997), report more severe and frequent fatigue compared with people without these problems. Elevations in baseline fatigue scores could have contributed to a larger increase in feelings of energy and lessened feelings of fatigue in the control conditions via regression to the mean (Campbell & Stanley, 1963). People with psychological distress also may show better adherence to placebo control conditions than to the chronic exercise intervention, and this could have resulted in a larger increase in feelings of energy and lessened feelings of fatigue in the control condition. Adherence information was poorly described and not always reported. However, in one of the investigations that involved chronic exercise alone, the participants were willing to spend 36% more time (45 min) at each session in the placebo control condition (stretching) than in the aerobic exercise training intervention (33 min; Steptoe et al., 1989). A third alternative concerns the poor sleep that characterizes people with symptoms of anxiety and depression disorders (Benca, Obermeyer, Thisted, & Gillin, 1992). Because stretching is associated with improved sleep for older adults (Tworoger et al., 2003) and poor sleep contributes to feelings of fatigue, it is possible that stretching increased feelings of energy and lessened feelings of fatigue to a greater extent among groups with higher levels of anxiety and depression. Last, it is possible that health education and stretching truly decreased feelings of fatigue among people experiencing anxiety and depression.

Secondary Moderators

The available literature did not allow for powerful inferential tests of the independent effect of a large number of moderators. Descriptive, univariate information was presented for the potential moderators of age, medical status, preintervention anxiety and depression symptom scores, exercise mode, and exercise program duration. Because additional primary research data are needed to adequately test whether these variables truly moderate the effect of chronic exercise on feelings of energy and fatigue, comments in this section are purposefully brief.

Age. Age has been inconsistently related to feelings of energy and fatigue (Pawlikowska et al., 1994). Although we did not find experiments focused on determining whether age moderates the effect of chronic exercise on feelings of energy and fatigue, a moderating effect of age is plausible. For example, the effect of chronic exercise on feelings of energy and fatigue might prove to be smaller among older adults because feelings of low energy are a barrier to the adoption of leisure time physical activity among older adults (Crombie et al., 2004). The potential moderating effect of age on changes in fatigue after chronic exercise may be indirect. For instance, the effect could be a function of the association between advancing age and the increased prevalence of fatigue-inducing chronic diseases.

Medical status. Chronic exercise was associated with increased feelings of energy and lessened feelings of fatigue among all medical groups considered in our analysis, including psychiatric, cardiovascular, cancer, and fibromyalgia patients. Yet, the results are not inconsistent with the hypothesis that the strength of the relation between chronic exercise and mental health varies depending on the chronic medical condition present (Stewart et al., 1994). The importance of reducing symptoms of fatigue during treatments for cancer (Ahlberg, Ekman, Gaston-Johansson, & Mock, 2003) and psychiatric conditions such as depression (Fava, Thase, & DeBattista, 2005) has been emphasized in recent years. Less attention has been paid to the possible effect of cardiac rehabilitation exercise programs on feelings of energy and fatigue, as researchers have focused on anxiety (Lavie & Milani, 2004), depression (Kugler, Seelbach, & Kruskemper, 1994), and general quality of life (Taylor et al., 2004) outcomes.

Anxiety and depression symptoms at baseline. It is unknown whether baseline anxiety or depression symptoms moderate increased feelings of energy and lessened feelings of fatigue following chronic exercise, because investigators have not directly pursued this question. Indeed, elevations in anxiety and depression symptoms have been used as exclusion criteria in studies of exercise training effects on chronic fatigue (Fulcher & White, 1997). Regardless, chronic exercise consistently has been associated with improved symptoms of anxiety and depression (Dunn et al., 2001). It is not implausible that improvements in symptoms of anxiety or depression following chronic exercise could be mediated by increased feelings of energy and lessened feelings of fatigue, but this hypothesis has not been tested. The results of one analogous study with cancer patients were interpreted as suggestive that improved fatigue with chronic exercise mediated the effect of chronic exercise on quality of life (Schwartz, 1999); however, caution is warranted because of the small sample size and absence of a control condition.

Exercise mode. Chronic aerobic exercise and strength training programs as well as those that combined elements of flexibility, strength, and aerobic exercise were all associated with increased feelings of energy and lessened feelings of fatigue. The small number of strength training experiments found in the literature search is consistent with the fact that the psychological consequences of strength training are infrequently studied and poorly understood compared with more commonly performed large-muscle dynamic exercise modes, such as walking and jogging. Given that symptoms of fatigue and depression often coexist, it is intriguing that significantly larger improvements in depression symptom scores have been reported following strength training compared with aerobic exercise training (North et al., 1990; Singh et al., 1997).

Exercise program duration. An important practical issue concerns the minimum exercise program duration needed to increase feelings of energy and lessen feelings of fatigue. The evidence summarized here suggests the absence of a positive linear relationship between exercise program duration and the magnitude of increased feelings of energy and lessened feelings of fatigue, as has been reported for symptoms of depression (North et al., 1990). Although exercise programs as short as 4–6 weeks were associated with an increase in feelings of energy and a decrease in feelings of fatigue (Mostert & Kesselring, 2002; Tsai et al., 2002), a key limitation of the available evidence is that week-to-week changes in feelings of energy and fatigue with the adoption and maintenance of regular exercise have not been examined, and no compelling experiment has investigated the influence of exercise program duration on feelings of energy and fatigue.

Broader Implications

The results of the primary moderator analysis highlight an issue that is broader than our focus on feelings of energy and fatigue. The broader issue is the difficulty in designing adequate placebo controls for investigations aimed at determining the effect of chronic exercise on psychological outcomes. Increased physical activity is often advocated for physiological and mental health benefits, and increasingly the recommendations are based on the available scientific evidence (Morgan, 1997). One important next step in this evolution toward science-based practice is the need to better understand which biological, psychological, and social aspects of a chronic exercise experience contribute to improved psychological health. Relevant neurobiological adaptations accompany chronic exercise (Dishman et al., 2006), and exercise interventions often involve substantial social interaction. Chronic social interaction has been shown to be as effective as a typical chronic exercise program (i.e., walking with another person, which combines exercise with social interaction) in improving symptoms of depression (McNeil, LeBlanc, & Joyner, 1991). Thus, if the effect of chronic exercise on symptoms of fatigue, depression, or other psychological outcomes is to be understood, it is critical to investigate or control for variables that are independent of exercise itself, such as social interaction. One exemplary study found that moderate-intensity chronic exercise of ~180 min per week improved depression scores when the exercise was performed in social isolation, compared with a stretching program that also was performed in isolation (Dunn, Trivedi, Kampert, Clark, & Chambliss, 2005). The weight of the current evidence suggests that chronic exercise increases feelings of energy and decreases feelings of fatigue. The evidence is inadequate, however, to rule out the possibility that experimental artifacts, such as a placebo effect, substantially account for the increased feelings of energy and decreased feelings of fatigue with chronic exercise.

Summary and Directions for Future Research

The cumulative evidence shows that chronic exercise programs are associated with an increase in feelings of energy and a decrease in feelings of fatigue that are large enough to be clinically important. The results of the quantitative synthesis we report are generally consistent with the results of our prior narrative review of the literature (O'Connor & Puetz, 2005). However, the present findings are generalizable to a larger number of studies, and they clarify how the effects of chronic exercise on feelings of energy and fatigue vary according to the type of control condition used and the specificity of the exercise intervention. Compared with studies with other designs, investigations that used a placebo control and examined chronic exercise alone were associated with a smaller mean effect. Our review suggests that this methodological influence was associated with three variables that were overrepresented in experiments that used chronic exercise alone with a placebo control—samples of older adults, samples with elevations in psychological symptoms of anxiety and depression, and the use of health education and stretching programs as placebo controls. Our review also reveals a need to improve the reporting of what participants specifically receive or do in control conditions. The cursory description of control conditions in many articles in this literature clouds the interpretation of the results and often precludes their independent replication.

Our review and analysis suggest other potentially useful directions for future research concerning the influence of chronic exercise on feelings of energy and fatigue. Important contributions would result from (a) investigations that reveal the groups and individuals who experience the largest and smallest increase in feelings of energy and decrease in feelings of fatigue after chronic exercise (e.g., do cancer patients with certain characteristics benefit psychologically from chronic exercise to a greater extent than other subgroups of cancer patients?), (b) experiments that systematically manipulate dimensions of the exercise stimulus (i.e., mode, frequency, session duration, intensity, and training duration) to learn the relative importance of each of these factors as well as what dose of chronic exercise is needed to bring about an increase in feelings of energy and a decrease in feelings of fatigue, and (c) experiments that show the extent to which chronic exercise interacts with other therapies for feelings of low energy and fatigue. The need for experiments that systematically pursue a better understanding of the strengths and limitations of the available tools for assessing feelings of energy and fatigue has been suggested previously (O'Connor, 2004).

One recommendation stands out from all others as having the biggest potential impact on this area of research. We recommend that researchers conduct experiments to determine the best placebo control for chronic exercise investigations. Scientific consensus about the types of comparison conditions that are optimal for elucidating independent and adjunctive effects of chronic exercise is fundamental to the advancement of knowledge about the theoretical and practical roles of chronic exercise in increasing feelings of energy and decreasing feelings of fatigue as well as other mental health outcomes.

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